The Next Step : In-situ Exploration of Venus by Balloon – Science Objectives and Mission Architecture

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Following the trailblazing flights of the 1985 twin Soviet VEGA balloons, missions to fly in the skies of Venus have been proposed to NASA's Discovery and ESA's Cosmic Visions programs, and are a key element of the 2009 NASA Venus Flagship Mission study. Such missions would answer fundamental science issues highlighted in a variety of high-level studies authorized by both NASA and the National Research Council in recent years, including the NRC Solar System Decadal Survey, various NASA roadmaps, and recommendations coming out of the Venus Exploration Analysis Group (VEXAG). In particular, long-duration, globe-circling balloon missions would uniquely address key questions of Venus's origin, evolution, and climate, by obtaining detailed, coupled measurements of (1) trace gases and cloud aerosols associated with Venus's radiative balance, its active photo- and thermo-chemistry, and dynamic meteorology and (2) densely sampled measurements of motions and local temperatures which characterize convective and wave processes that transport momentum and heat both vertically and horizontally, a key to understanding Venus' global super-rotation. As an example of what can be done with small class missions (less than ~$500 M), the Venus Atmospheric Long-duration Observatory for in-situ Research (VALOR) Discovery mission concept will be discussed. Floating in Venus's rapid windstream for several weeks within a relatively benign altitude range of 54 -57 km (~30C, ~0.5 bar), VALOR's balloon-borne science observatory will sample rare gases and trace chemicals and measure vertical and horizontal motions and cloud aerosols within Venus's dynamic middle cloud layer. Tracked by an array of Earth-based telescopes and the carrier spacecraft that flies above the backside of the planet as viewed from Earth, all three components of winds - zonal, meridional, and vertical - will be measured with unprecedented precision over nearly all longitudes. Although the route the balloon will take is somewhat uncertain due to the large uncertainty in meridional winds, VALOR will likely explore a variety of distinctive dynamical/meteorological regimes within Venus's energetic atmosphere as it alternately flies in daytime and nighttime conditions and as it drifts poleward over several weeks from the convective temperate region through the wave-populated mid-latitudes to the exceedingly cloudy north polar vortex region. Riding the gravity and planetary waves of Venus à la the VEGA balloons, VALOR would sample in particular the chemistry and dynamics of Venus's sulfur-cloud meteorology, including the frequency and strength of lightning. As well, the mission will test a variety of scenarios for the origin, formation, and evolution of Venus by sampling all the noble gases and their isotopes, especially the heaviest elements never before reliably measured, xenon and krypton. Thus, VALOR will complete the measurements of noble gases for the three terrestrial planets, Earth, Mars, and Venus. Altogether, VALOR provides key information for comparative planetological studies of the terrestrial planets as it helps develop our fundamental understanding of (1) the circulation of Venus, including the roles that solar thermal tides, other planetary waves, and convective and meridional motions play in powering the planet's poorly-understood super-rotation, (2) the nature of Venus's sulfur cycle, key to Venus's current climate, and (3) how our neighboring world formed and evolved over the aeons to its present un-Earthlike state of extreme environmental conditions.